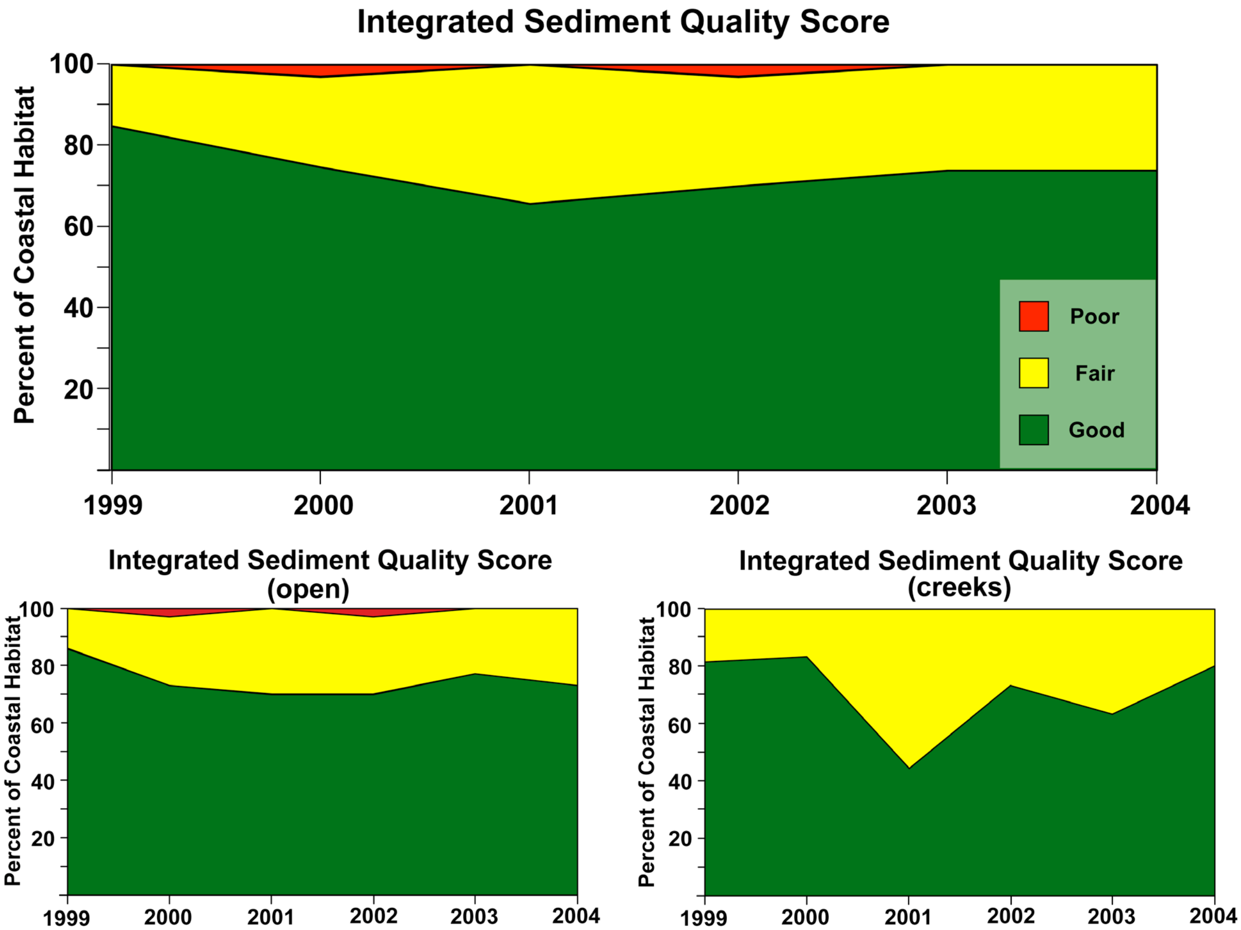


Figure 3.3.3. Proportion of the South Carolina's estuarine habitat that ranks as good (green), fair (yellow) or poor (red) using the integrated sediment quality score when tidal creek and open water habitats are combined and compared on an annual basis, and for tidal creek and open water habitats considered separately.

3.4 Biological Condition

Phytoplankton

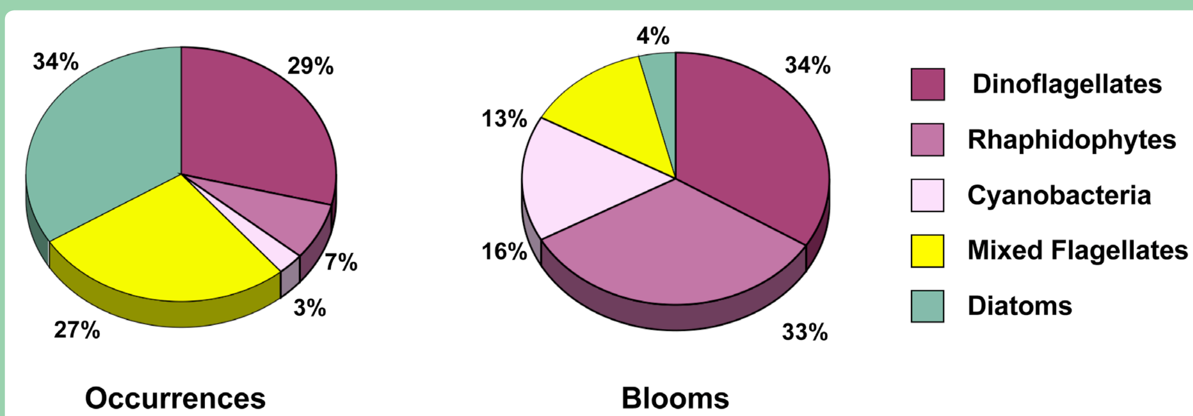
Phytoplankton biomass and composition serve as valuable indicators of estuarine health because these primary producers respond rapidly to increases in nutrient loading. Even short-term increases in nutrient inputs can promote blooms of algal species that are often present but not overabundant in balanced, healthy estuarine systems. Increased nutrient inputs promote a complex set of environmental responses, beginning with shifts in algal composition and leading to blooms of harmful species that have deleterious impacts on biota (Bricker *et al.,* 1999). Harmful species are defined by the potential to produce blooms or toxins that have negative effects on biological systems (causing fish kills for example) and in some cases cause human health problems (such as paralytic shellfish poisoning).

Most harmful algal species fall within the cyanobacteria, dinoflagellate and raphidophyte groups, although not all species within these taxa are harmful and some may appear within the diverse assemblages of pristine estuarine systems. These

Fishkill in a stormwater detention pond caused by a toxic cyanobacterial bloom. Photo credit: SCAEL

Box 3.4.1 Harmful Algae and Coastal Stormwater Ponds

In coastal stormwater ponds, the algal assemblage is dominated by harmful species that frequently produce blooms (> 1000 cell/ml). The algae producing these blooms are most frequently classified as dinoflagellates, raphidophytes, and cyanobacteria, which all have potentially toxic species. In the rapidly urbanizing South Carolina coastal zone, intensive landscape maintenance and turf management are significant sources of non-point source pollutant and nutrient loadings (Lewitus, *et al*., 2003). The stormwater best management practice of choice in this region is wet detention ponds. Typically, stormwater is piped directly into the ponds, but their capacity for processing pollutants is limited. These highly eutrophic ponds are "hot spots" for harmful algal blooms, many associated with measured toxins, fish kills, or shellfish health effects. Pond nutrient accumulations may also impact estuarine eutrophication through surface or groundwater transport (Pinckney *et al*., 2001). The pie charts below show the percent occurrence (by group) of all species and percent blooms (by group) of all blooms (>1000 cells/ml) between 2000 and 2005. During this period 325 blooms were recorded in brackish detention ponds and 25 in South Carolina's estuarine and coastal environment. Note that most of the blooms are attributed to dinoflagellates, raphidophytes and cyanobacteria.



The percent occurrence and percent of blooms of harmful species in eutrophic coastal locations (detention ponds and nearby impaired estuaries) from the larger South Carolina Harmful Algal Bloom database between 2000 and 2005.

taxa do, however, respond rapidly to increased nutrient levels and will dominate the biomass in enriched brackish environments (Ramus *et al.,* 2003). Unfortunately, there are far too many examples of these enriched brackish environments in South Carolina coastal zone. Stormwater ponds along the coast serve as incubators for harmful algal blooms and appear to be acting as a source of these harmful species into the adjacent estuaries (Box 3.4.1).

In contrast to this scenario of eutrophic water which reflects the anthropogenic effects of development, the majority of sites investigated in the 2003-2004 SCECAP program appeared to be in good condition and supported a diverse and desirable phytoplankton assemblage. The CHEMTAX evaluation of the percent biomass contribution by taxa demonstrated that 86-88% of the biomass was "healthy" (diatoms or mixed flagellates) and 13-14% was potentially harmful (dinoflagellates, raphidophytes or cyanobacteria). Diatoms are common in pristine estuaries and contribute efficiently to the food web (Lewitus *et al*., 1998). They contributed 48% of the biomass in the open water habitats and 41% of the biomass in the tidal creek habitats. Mixed flagellates were also dominant, and, while not as effective in transferring carbon and energy through the aquatic food web as the diatoms, they are considered desirable phytoplankton. The average relative biomass contributed by mixed flagellates was 39% in open water and 45% in tidal creek habitats (Figure 3.4.1). The smallest fraction of the biomass was contributed by the potentially harmful taxa including some dinoflagellates, raphidophytes and cyanobacteria. Only 13% of open water and 14% of the tidal creek site biomass was attributed to harmful taxa (Figure 3.4.1).

While the average percentage of harmful species at SCECAP sites is low for both tidal creek and open sites, there were some stations where the biomass of potentially harmful species exceeded 20% (Figure 3.4.2). Dinoflagellate percent biomass was elevated at six stations, while percent cyanobacterial biomass exceeded 20% at 12 stations. The station with the highest percent harmful cyanobacteria had a toxicity bioassay score indicative of a high probability of toxic sediments, and the station with the highest percent dinoflagellate relative biomass had an

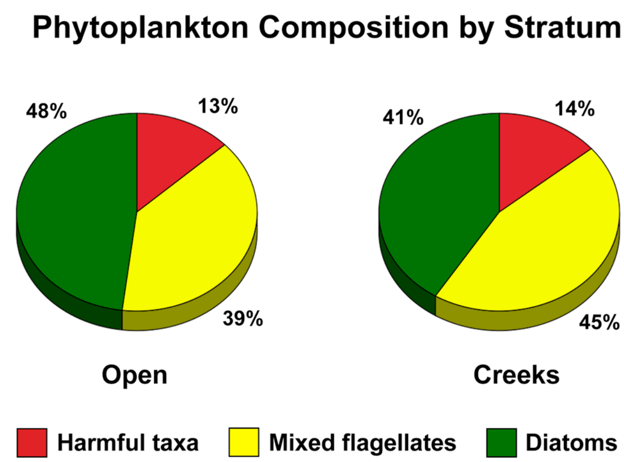


Figure 3.4.1. The percent contribution of diatoms, harmful taxa, and mixed flagellates to total phytoplankton community pigment biomass based on the mean of 2003-2004 samples from SCECAP open water and creek sites.

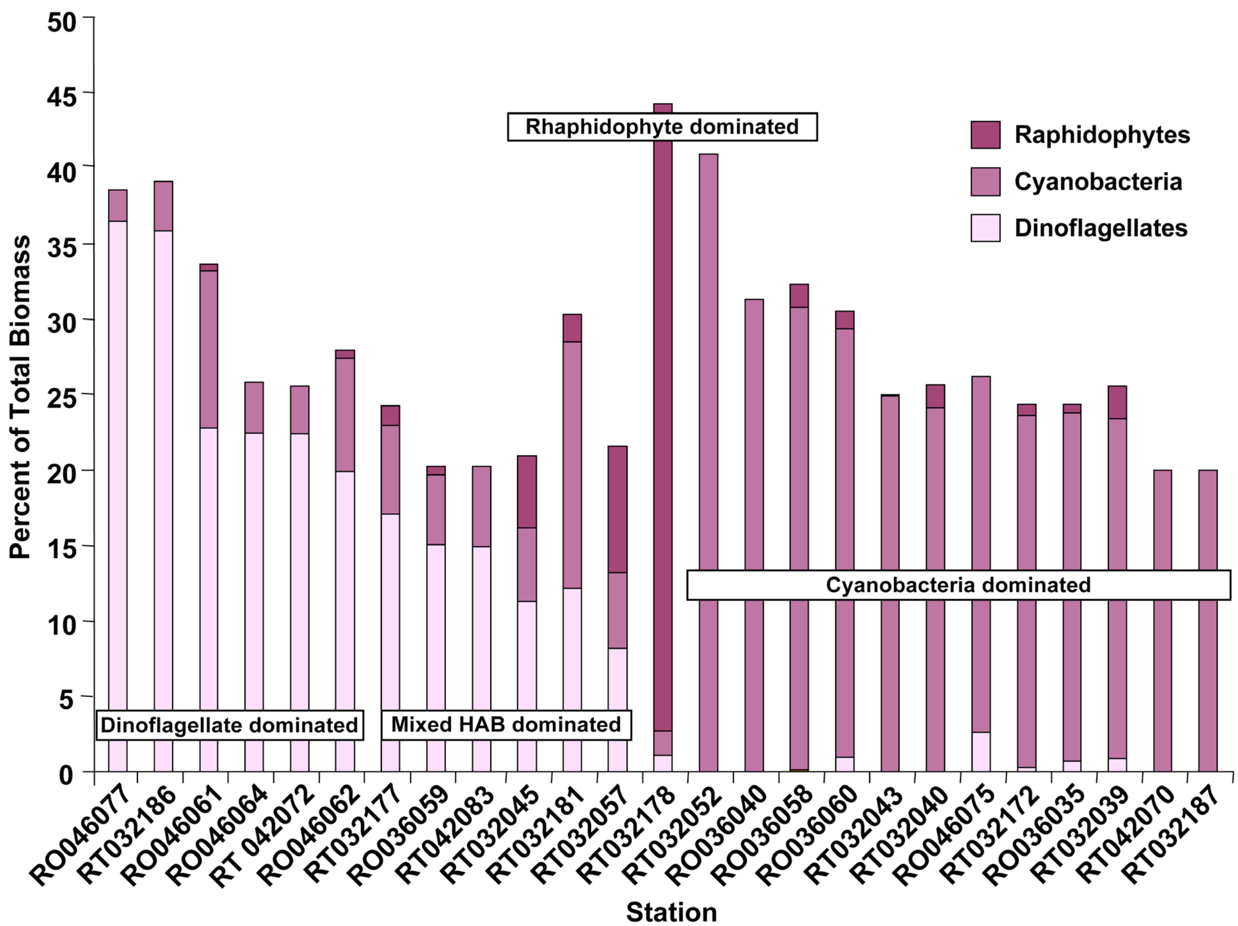


Figure 3.4.2. Percent biomass of harmful groups from stations with >20% of biomass attributed to potentially harmful taxon.

ERM-Q score indicative of high contaminant risk. Six stations had a mixed assemblage of harmful algal taxa and one station had primarily raphidophytes with *Heterosigma akashiwo* comprising 45% of the algal biomass (Figure 3.4.2). This station was within the Bulls Bay region where the South Carolina Algal Ecology Laboratory (SCAEL) documented a large (50 mi^2) offshore bloom of *Heterosigma akashiwo* in April 2003 (Keppler *et al.,* 2005).

The effects of the prolonged drought from 1999-2002 and a return to higher rainfall during 2003 were apparent in a decrease in salinity and relatively high nutrients levels during 2003 (see Section 3.2). Species that are generally confined to salinities of < 5 ppt include the cyanobacteria, euglenoids, and chlorophytes. These three groups were not present in the samples collected during 2001-2002, but did appear in the 2003 assemblages at seven tidal creek sites and nine open water sites (Figure 3.4.3). The salinity of the sites containing the euglena species varied from 0.1- 17.9 ppt, while the average salinity at sites with cyanobacterial species present was 13.9 ppt for creeks and 14.1 ppt for open water sites.

Another group which increased in diversity during 2003-2004 was the raphidophytes. These potentially ichthyotoxic (fish-killing) species tend to occur in brackish water ranging from 10-25 ppt, and can bloom rapidly in response to nutrient-rich freshwater inflows (Honjo, 1993). The salinity ranges of the raphidophyte species noted in the 2003-2004 SCECAP samples was from 12 - 29 ppt (Figure 3.4.3).

While the overall biomass of the phytoplankton is attributed to desirable species, there were harmful species present during the 2003-2004 sampling period. Table 3.4.1 lists the number of occurrences in the SCECAP phytoplankton database of the potentially harmful species. The cyanobacterial species noted are all potential bloom formers and most can produce toxins (hepatotoxins and neurotoxins). Only one diatom species of concern was documented, but this species (*Pseudo-nitzschia* cf *delicatissima*) can produce domoic acid, a potent neurotoxin (Horner *et al*., 1997). Many of the dinoflagellates listed are capable of producing blooms and have been associated with fish kills in South Carolina and around the world. A few of the known toxin producers documented by SCECAP included *Alexandrium*, *Gambierdiscus* and *Prorocentrum.* The final group noted are the raphidophytes that frequently have been associated with fishkills in South Carolina stormwater

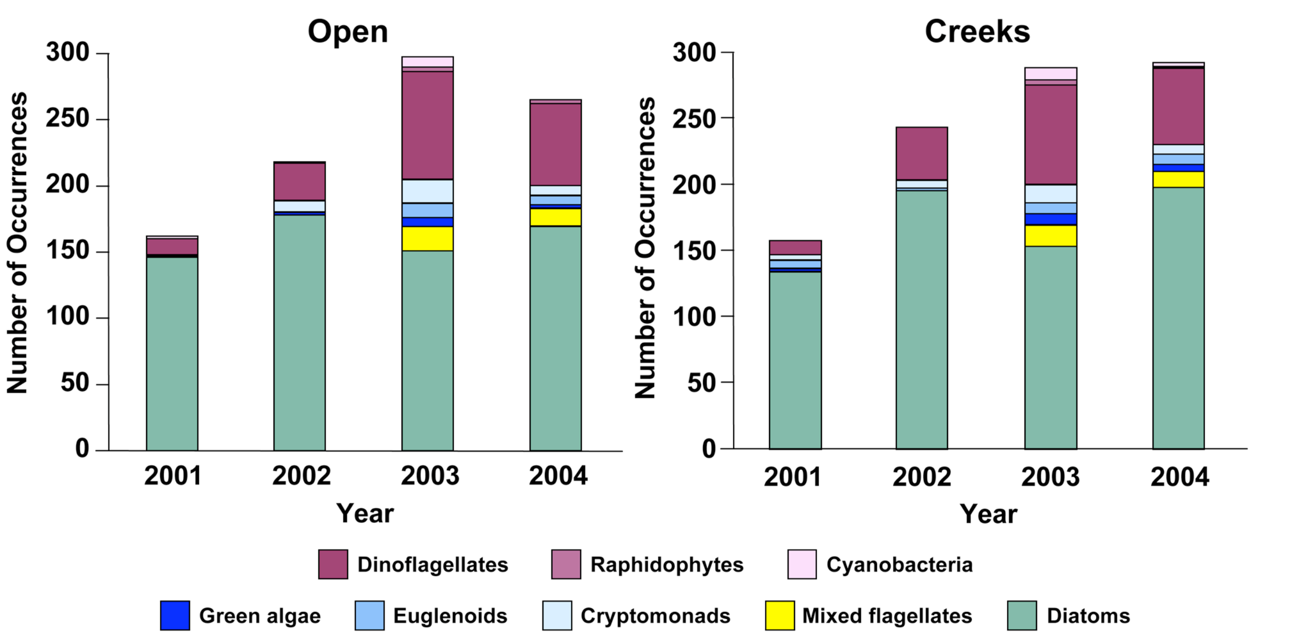


Figure 3.4.3. Occurrence of dominant taxonomic groups in open water and tidal creek sites. The number of taxa increased during the current study period coincident with a decrease in salinity, and the additional groups (green algae, euglenoids, and cyanobacteria) tend to occur in lower salinity water.

Table 3.4.1 Number of open water and tidal creek stations where potentially harmful phytoplankton species were identified. Included are whether each species is toxin-forming (toxic) or bloomforming (blooms) as well as the toxins and/or ecological effects produced.

Phytoplankton Species	Open Water	Tidal Creek	HAB Category	Known Toxins, Effects
Cyanobacteria				
Anabaena sp.		1	toxic	Anatoxins, Saxitoxins, Microcystins, LPS
Aphanizomenon sp.		1	toxic	Saxitoxins, Cylindrospermopsins, LPS
Microcystis aeruginosa		1	toxic	Microcystins, LPS
Microcystis incerta		1	blooms	
Oscillatoria sp.	6	6	toxic	Anatoxin, LPS
Planktothrix sp.		1	toxic	Anatoxin, LPS
Pseudanabaena sp.	1	1	toxic	unknown neurotoxin
Spirulina sp.	1		blooms	
Diatoms				
Pseudo-nitzschia cf delicatissima	1	1	toxic	Domoic acid
Pseudo-nitzschia sp.	9	8	some toxic	Domoic acid
Dinoflagellates				
Akashiwo sanguinea	14	20	blooms	
Alexandrium sp.	1		toxic	Hemolysin, PSP-causing compounds
Amphidinium sp.	5	2	toxic	Hemolysins
Gambierdiscus sp.	1		some toxic	Ciguatoxin- and Maitotoxin-like compounds
Gyrodinium pingue	4	7	blooms	associated with fishkills in SC
Gyrodinium instriatum	1	1	blooms	associated with fishkills in SC
Heterocapsa rotundata	28	20	blooms	associated with fishkills in SC
Heterocapsa triquetra	1		blooms	associated with fishkills in SC
Karlodinium micrum	16	8	toxic	karlotoxin, ichthyotoxic
Krypto-imposter	4	12	blooms	associated with shellfish stress in SC
Kryptoperidinium foliaceum	4	21	blooms	associated with shellfish stress in SC
Pfiesteria-like organism	2	5	toxic	associated with fishkills in SC
Prorocentrum c.f. lima		1	toxic	Okadaic acid, Dinophysis toxins 1 & 2
Prorocentrum micans	1		blooms	associated with fishkills in SC
Prorocentrum minimum	4	3	toxic	Unknown toxins
Prorocentrum sp.		1	some toxic	Okadaic acid, Dinophysis toxins 1 & 2
Raphidophytes				
Chattonella subsalsa	2		blooms	associated with fishkills in SC
Chattonella verruculosa		1	toxic	icthyotoxic
Fibrocapsa japonica	1		toxic	icthyotoxic
Heterosigma akashiwo	2	2	toxic	icthyotoxic
Heterosigma sp.	1	2	toxic	icthyotoxic

ponds. The raphidophytes *Heterosigma akashiwo, Fibrocapsa japonica*, and *Chattonella subsalsa*, also found by SCECAP in South Carolina's coastal waters, have been implicated in numerous fish kills globally (Honjo, 1993).

While none of these species were present in high abundance and no toxins were detected in the samples collected for the SCECAP study, they are present and potentially capable of responding rapidly to future anthropogenic nutrient enrichment. It is imperative that the development of our coastline be tempered by thorough urban planning and effective watershed management in order to prevent harmful algal blooms and ensure the health of our estuaries.

Benthic Communities

Benthic macrofauna serve as ecologically important components of the food web by consuming smaller organisms living in or on the sediments, detritus, or planktonic food sources and in turn serving as prey for finfish, shrimp, and crabs. Benthic macrofauna are also relatively sedentary, and many species are sensitive to varying environmental conditions. As a result, benthic organisms are important biological indicators of water and sediment quality and are useful in monitoring programs to assess overall coastal and estuarine health (Hyland *et al*., 1999; Van Dolah *et al*., 1999).

Mean density of benthic organisms across all stations sampled during the 2003-2004 study period varied from 63 to 37,113 individuals/m^2 (mean= 3,628 individuals/m^2). The mean density of organisms collected in open water habitats (4,182 individuals/m^2) was greater than the density in tidal creek habitats (3,076 individuals/m^2), although the difference was not statistically significant ($p = 0.952$, Figure 3.4.4). The density of benthic organisms in open water habitats has been consistently higher than in tidal creek habitats in all three surveys conducted by SCECAP to date (Van Dolah *et al*., 2002a; 2004a). The mean density of organisms collected during the 2003-2004 study period was 25% lower than the mean density collected in the 1999-2000 study period (average = 4,722 individuals/m^2) and 30% lower than those collected in 2001-2002 (average = 5,208 individuals/m^2). The first two study periods (1999-2002) occurred during a drought period in South Carolina (South Carolina State Climatology Office), while the current study period began after the drought was lifted in April, 2003. The differences in benthic faunal density may reflect changes in salinity between the previous study periods when drought conditions persisted (Van Dolah *et al*., 2002a; 2004a) and the current study period when more normal rainfall patterns returned (see section 3.2 and Box 3.4.2).

The overall number of species (species richness: S) varied from two to 64 taxa per grab (average = 17), and species diversity (H') varied from 0.40 to 4.49 (average = 2.62). The mean number of species

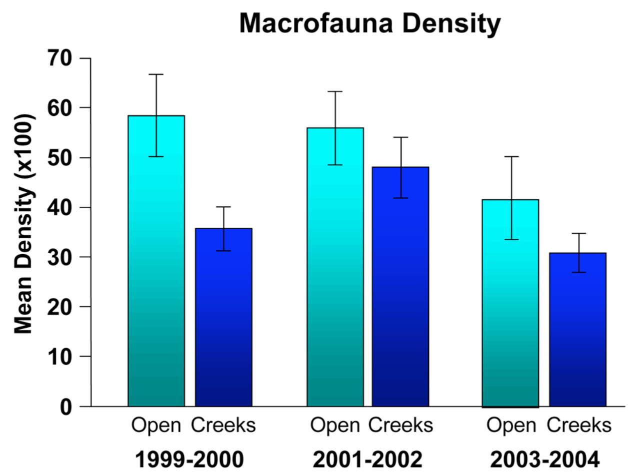


Figure 3.4.4. Mean density (number per m^2) of benthic fauna collected in open water and tidal creek habitats during the three study periods.

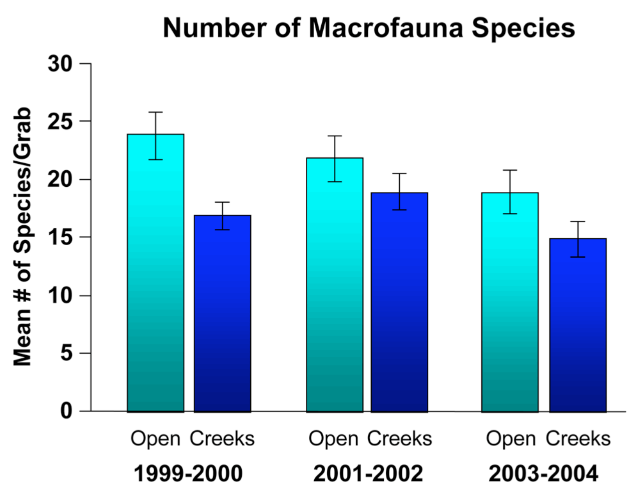
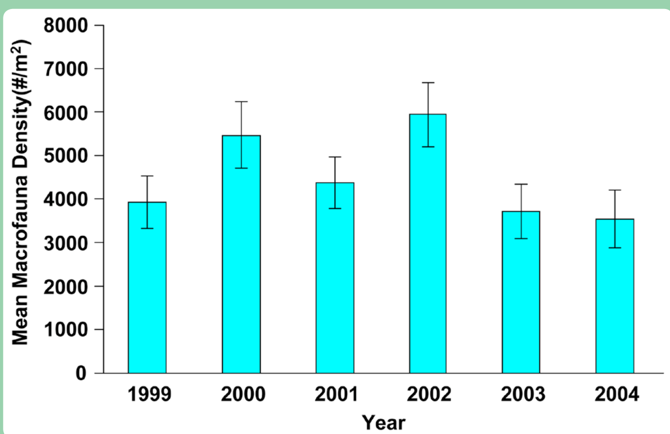


Figure 3.4.5. Mean number of species of benthic fauna collected in open water and tidal creek habitats during the three study periods.

Box 3.4.2 Rainfall, Salinity and Benthic Invertebrates

How does salinity affect estuarine benthic communities?

Salinity in an estuary varies with daily tides, season, volume of fresh water inflow, and proximity to the open ocean. Estuarine salinities are usually highest at the mouth of a river where ocean water enters, and lowest upstream where freshwater inflow is greatest. However, drought conditions can significantly alter the water quality of an estuary, particularly by allowing high salinity water to penetrate further upstream. Salinity is the major natural environmental factor controlling the distribution of benthic organisms in estuaries (Attrill & Power, 2000; Magnien *et al*., 1987). While benthic estuarine fauna are adapted to handling a fairly broad range of salinities, unusually high or low salinities and large changes in salinity can negatively affect their survival, growth and reproduction. During the current SCECAP study period, average salinity decreased and salinity ranges increased in both tidal creek and open water habitats as compared to previous study periods. Concurrent with this change was a 30% decrease in the mean number of organisms per m^2 collected by SCECAP sampling in South Carolina's sediments. Additionally, seven stations sampled in the current study period had salinity ranges greater than 20 ppt throughout a 25-hour monitoring period. Six of those stations also had low densities of benthic organisms ($<1000/m^2$), suggesting evidence of biological stress. This trend may reflect salinity effects directly, but it also may reflect other factors associated with increased terrestrial runoff, such as increased contaminant loads.



Abundance of benthic organisms (mean number per m^2) collected each year since the start of SCECAP monitoring in 1999.

and overall species diversity per grab were higher in open water habitats (S = 18.8, H' = 2.75) than in tidal creek habitats (S = 15.2, H' = 2.49) during the current study period (Figure 3.4.5). Although not significant, the trend of higher values at open water stations was also observed in the two previous study periods. No significant differences were observed in the average number of species or diversity estimates per grab among the three survey periods conducted to date, when all stations were considered collectively or when both habitat types were compared separately.

In order to compare the general taxonomic composition of organisms collected during each study period, all benthic species were classified into one of four groups: polychaetes, amphipods, mollusks, or other taxa (primarily oligochaetes, nemerteans, isopods, and decapods). The mean abundances of amphipods and mollusks were significantly greater in open water than in tidal creek habitats ($p = 0.013$; $p=0.032$, respectively). Polychaetes and other taxa were found in greater abundances in tidal creek habitats than in open water habitats, but these differences were not significant ($p > 0.05$). The percent abundance of polychaetes observed in both habitat types during 2003-2004 was very similar to that observed in the 1999-2000 survey, but about 10% lower than observed during the 2001-2002 survey period (Figure 3.4.6). Slightly higher percentages of amphipods and lower percentages of other taxa were found during the current sampling period at open water habitats when compared to the two previous study periods, while the opposite trend was observed at tidal creek habitats (Van Dolah *et al*., 2002a; 2004a). Minimal

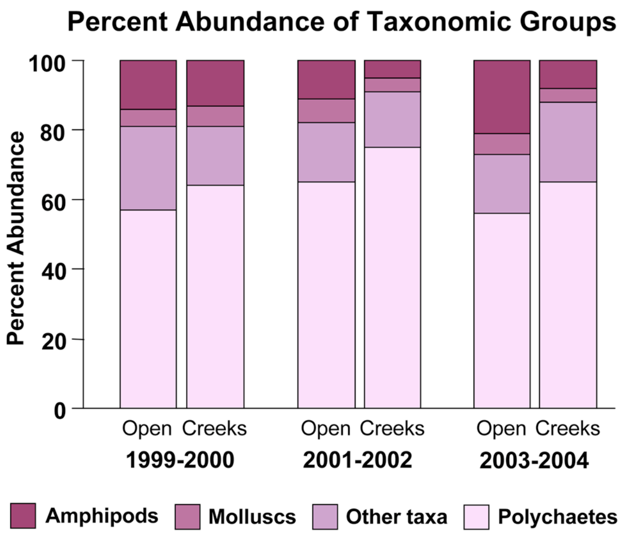


Figure 3.4.6. Percent abundance of organisms representing general taxonomic groups collected in benthic grabs at open water and tidal creek sites during the three study periods.

changes in mollusk abundances were observed across all study periods.

The number of species in each taxonomic category varied by habitat type. Open water stations collectively included 144 polychaete species, 48 amphipod species, 56 mollusk species, and 77 other taxa. Tidal creek stations collectively included 119 polychaete species, 38 amphipod species, 47 mollusk species, and 64 other taxa. There were significantly more amphipod species found at open water stations than at tidal creek stations sampled during the current study ($p = 0.009$). The number of species representing the other taxonomic groups (polychaetes, mollusks, and other taxa) were not significantly different between the habitat types. There were few significant differences between study years with respect to the number of species representing various taxonomic categories in either open water or tidal creek stations. One exception was a significantly greater number of polychaete species in tidal creek habitats during the 2001-2002 study period than during the 2003-2004 study period ($p = 0.037$).

The five dominant taxa collected during the 2003-2004 study period comprised 29% of the overall abundance across all stations (Table 3.4.2). These taxa included the polychaetes *Streblospio benedicti*, *Scoletoma tenuis*, *Mediomastus* sp. and *Tharyx acutus*, and the amphipod *Ampelisca abdita*. Of the five most abundant taxa, only *A. abdita* occurred at less than 50 percent of the stations sampled (Table 3.4.2). Nemertean worms (the 24th most abundant taxon) occurred at the largest percentage of stations (65%). Two of the five dominant taxa collected in 2003-2004, *S. benedicti* and *S. tenuis*, were also among the five dominant taxa collected in the 1999-2000 and 2001-2002 study seasons (Van Dolah *et al*., 2002a; 2004a).

In open water habitats, the five most abundant taxa also comprised 29% of the total abundance and included the polychaetes *S. tenuis*, *S. benedicti*, *Sabellaria vulgaris* and *Exogene* sp. and the amphipod *A. abdita*. The polychaete *Caulleriella* sp. was among the top five organisms collected in open water habitats in the previous two study periods, but was substantially less abundant during 2003-2004 (Table 3.4.2). The five most abundant taxa in tidal creek habitats together comprised over 38% of the total abundance of benthic tidal creek fauna and included *S. benedicti*, *S. tenuis*, *T. acutus*, *Mediomastus* sp. and the oligochaete *Tubificoides wasselli*. *Streblospio benedicti*, *T. wasselli*, and *S. tenuis* have been among the top five taxa collected in tidal creek habitats during all three study periods.

Streblospio benedicti, the numerically dominant species overall and in tidal creek habitats, was found in significantly greater abundances in tidal creek habitats than in open water habitats ($p = 0.004$). The same trend was observed in the 1999-2000 study period, but *S. benedicti* was found in significantly greater abundances in open water habitats during the 2001-2002 study period (Van Dolah *et al*., 2002a; 2004a). *Streblospio benedicti* is generally sensitive to changes in salinity, and its abundance tends to decrease at lower salinities (Reish, 1979). Over the three study periods, the average salinity in tidal creek habitats has consistently decreased (see section 3.2), and *S. benedicti* abundances have as well. The second most abundant organism in tidal creek habitats was the oligochaete *T. wasselli*, but it was not particularly abundant in open water habitats. During previous study periods, *T. wasselli* was among the top ten numerically dominant organisms in both open water and tidal creek habitats. However, *T. wasselli* prefers a mesopolyhaline (5-30 ppt) environment. The amount of coastal estuarine habitat in this salinity

Table 3.4.2. Densities and percent occurrences of the 50 numerically dominant benthic organisms collected in 2003 and 2004, which represent 82% of the overall abundance. A = amphipod, M = mollusk, P = polychaete, O = other taxa.

				Open Water		Tidal Creek	
Species Name		Mean Total Abundance at All Stations (#/grab)	% of Stations Where Present	Mean Abundance by Station (#/grab)	% of Stations Where Present	Mean Abundance by Station (#/grab)	% of Stations Where Present
Streblospio benedicti	P	1640	63	7	52	20	75
Scoletoma tenuis	P	947	52	9	43	7	60
Ampelisca abdita	A	925	38	13	33	2	42
Mediomastus sp.	P	686	57	7	57	4	57
Tharyx acutus	P	673	50	6	48	5	52
Sabellaria vulgaris	P	666	22	10	28	1	15
Tubificoides wasselli	O	657	34	2	32	9	37
Exogone sp.	P	553	29	7	35	2	23
Tubificoides brownae	O	412	46	4	43	3	48
Actiniaria	O	412	21	3	23	4	18
Scoloplos rubra	P	305	44	2	35	4	53
Paraprionospio pinnata	P	296	36	3	38	2	33
Polydora cornuta	P	273	28	1	23	4	33
Parapionosyllis sp.	P	262	12	3	17	1	7
Nereis succinea	P	233	43	1	37	2	48
Tubificidae sp. b	O	222	30	2	32	1	28
Caulleriella sp.	P	212	13	0	15	3	12
Spiochaetopterus costarum oculatus	P	200	32	2	32	2	32
Ampelisca verrilli	A	197	16	2	20	1	12
Melita nitida	A	196	23	1	20	2	25
Heteromastus filiformis	P	195	43	0	27	3	58
Scolecolepides viridis	P	191	10	2	8	2	12
Nemertea	O	183	65	1	68	2	62
Aphelochaeta sp.	P	180	26	1	22	2	30
Tubificidae	O	177	25	1	18	2	32
Polydora socialis	P	168	27	1	32	2	22
Carinomella lactea	O	160	33	2	35	1	32
Batea catharinensis	A	151	22	2	28	0	15
Cyathura burbancki	O	142	21	2	27	1	15
Paracaprella tenuis	A	135	17	2	22	1	12
Mediomastus californiensis	P	134	14	2	15	0	13
Protohaustorius deichmannae	A	132	8	2	13	0	2
Tellina agilis	M	131	27	2	32	1	22
Aricidea wassi	P	126	13	2	25	0	2
Polycirrus sp.	P	125	7	2	7	1	7
Tubificoides heterochaetus	O	119	12	1	10	1	13
Aricidea bryani	P	119	24	1	23	1	25
Mediomastus ambiseta	P	117	23	1	28	1	18
Acanthohaustorius millsi	A	114	6	2	8	0	3
Monticellina sp.	P	112	19	1	22	1	17
Leptonacea sp.	M	111	16	2	23	0	8
Phoronida	O	109	16	1	15	1	17
Cirrophorus sp.	P	103	25	1	30	1	20
Unciola serrata	A	101	5	2	10	0	0
Sphenia antillensis	M	97	23	1	25	0	22
Cirratulidae	P	96	31	1	30	1	32
Streptosyllis sp.	P	86	21	1	25	0	17
Leitoscoloplos fragilis	P	81	34	1	38	1	30
Glycera americana	P	78	44	1	45	1	43
Pelecypoda	M	73	33	1	40	0	25

range was approximately 8% lower (see section 3.2) than we observed in the the 2001-2002 study period, a loss that may account for the lower *T. wasselli* abundance. In 2003-2004, *Scoletoma tenuis* was the second most numerically abundant organism over all habitat types and was among the top five dominant organisms found in open water habitats. There were no significant differences in abundances of *S. tenuis* in tidal creek versus open water habitats in the current study ($p = 0.282$).

SCECAP uses a single multi-metric benthic index of biological integrity (B-IBI) to distinguish between degraded and undegraded environments in southeastern estuaries (Van Dolah *et al*., 1999). A number of metrics (i.e., abundance, number of species, and abundance of sensitive taxa) have been integrated into the B-IBI in order to summarize benthic community condition in coastal habitats. About 70% of South Carolina's open water and 71% of tidal creek habitat sampled in 2003-2004 had a healthy benthic community (Table 3.4.3). There has been an apparent decrease in the amount of habitat supporting healthy benthic communities (ie., coding as good benthic condition) since the initial 1999-2000 survey (open water = 16% decline, tidal creek = 13% decline; Van Dolah *et al*., 2002a, 2004a). The amount of South Carolina's coastal habitat that supported benthic communities having some evidence of possible degradation (ie., coding as fair benthic condition) was approximately 22% in open water habitat and 21% in tidal creek habitats. Both habitat types have shown an increase in the percentage of habitat having only fair benthic community condition since the 1999-2000 study (Table 3.4.3). Approximately 8% of the coastal open water and tidal creek habitat had a poor benthic community condition, which represents an approximate increase by 6% in open water habitat and 4% in tidal creek habitat since the inception of the program.

Table 3.4.3. Percent of habitat with B-IBI values indicating good (undegraded), fair (marginally degraded), or poor (degraded) benthic conditions.

	Percent of Habitat B-IBI					
	Open Water			Tidal Creek		
Study Period	Good	Fair	Poor	Good	Fair	Poor
1999-2000	86	12	2	84	12	4
2001-2002	83	14	3	69	27	4
2003-2004	70	22	8	71	21	8

When evaluating B-IBI scores on a yearly basis, there is clearly a trend of decreasing percentage of coastal habitat which supports healthy benthic communities in South Carolina (Figure 3.4.7), with associated increases in the percentages of coastal habitats which have fair and poor benthic community condition. While we didn't observe similar trends in water quality or sediment quality conditions over the course of the study, there has been an increase in ERM-Q (see section 3.3) in coastal areas. The contribution of rising contaminant levels to the decreasing B-IBI is unclear, particularly considering the concomitant changes in salinity during this time.

Finfish and Crustacean Communities

South Carolina estuaries support a diverse array of fish and crustaceans that are dependent on estuarine habitats for food and shelter (Joseph, 1973; Mann, 1982; Nelson *et al*., 1991). Estuaries represent a naturally stressful environment due to broad fluctuations in physical conditions (temperature, salinity, etc) and biological pressures such as predation and competition with other species. In addition, anthropogenic stressors such as recreational and commercial fishing, boating activity, upland development, storm water inputs, and habitat modifications are all placing additional pressures on South Carolina's essential estuarine habitats. Changes to these coastal ecosystems will ultimately lead to changes in the fish and crustacean communities that are dependent upon them (Monaco *et al*., 1992).

Community Composition:

A total of 14,912 organisms representing 72 species were collected by trawl during the 2003-2004 survey (data online). Mean faunal density across all stations varied from four to 4,790 individuals per hectare (individuals/ha) with an overall average of 714 individuals/ha. The mean density in tidal creeks (1040 individuals/ha) was more than twice the mean density in open water habitats (388 individuals/ha), a statistically significant difference ($p < 0.001$). The trend of higher mean faunal densities in tidal creek

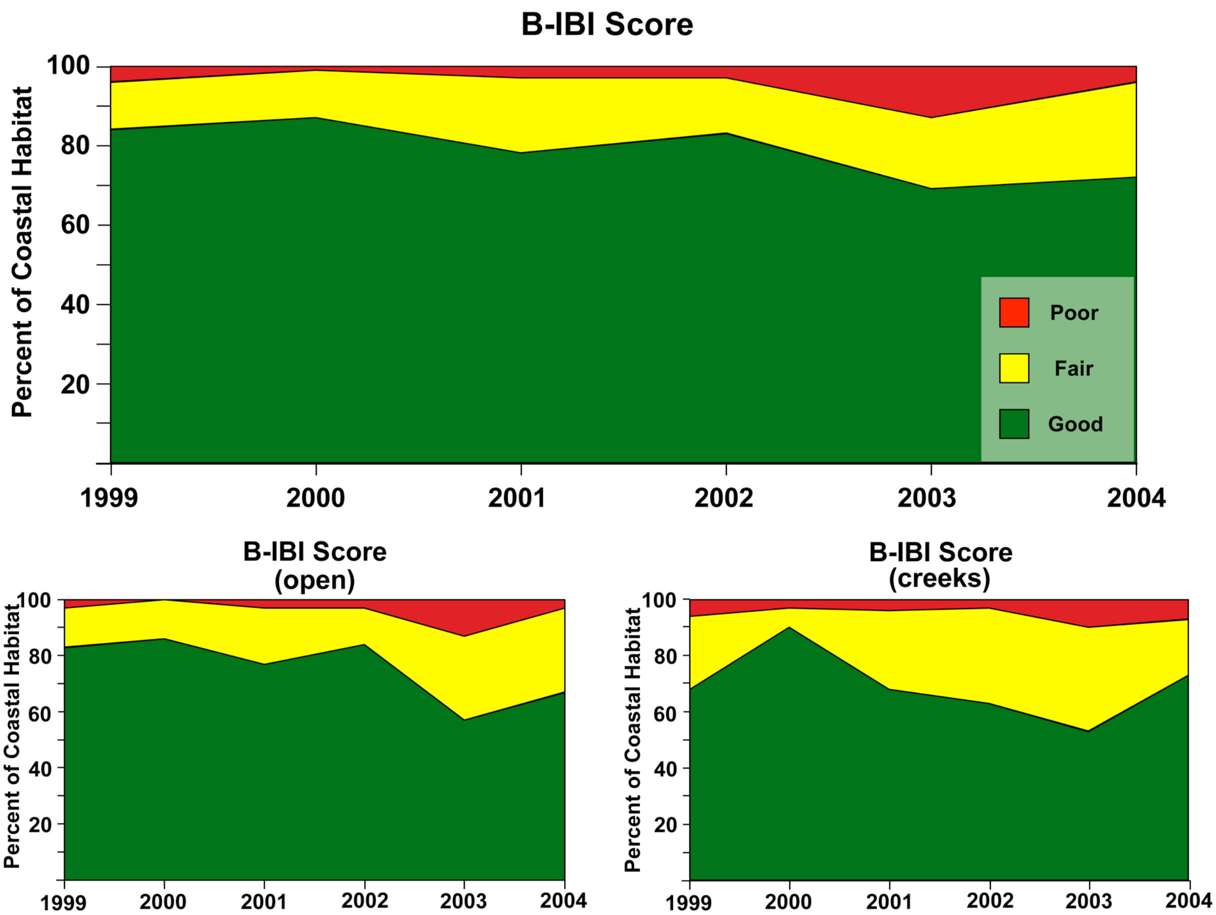


Figure 3.4.7. Proportion of the South Carolina's estuarine habitat that ranks as good (green), fair (yellow) or poor (red) using the benthic index of biological integrity (B-IBI) values compared on an annual basis when tidal creek and open water habitats are combined and for tidal creek and open water habitats considered separately.

stations compared to open water stations has been observed in all three of the survey periods evaluated by SCECAP to date (Van Dolah *et al*., 2002a, 2004a).

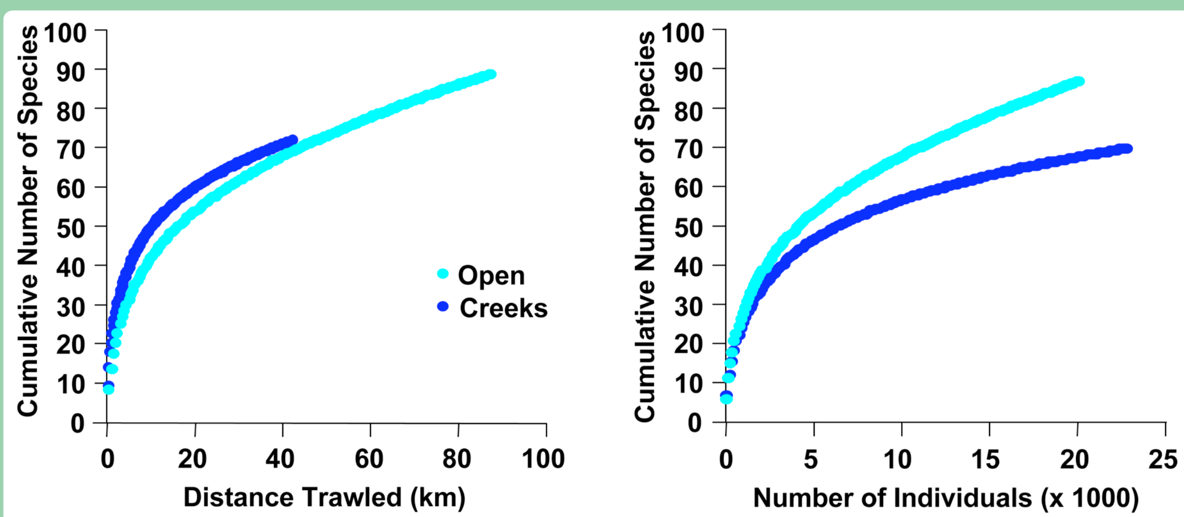
The average number of species collected across all stations was 5.9 and varied from 1 to 15 per trawl. Evenness values (J') averaged 0.66 and varied from 0.00 to 1.00, and overall community diversity (H') averaged 1.62 and varied from 0.00 to 2.96. The mean number of species per trawl was slightly higher in tidal creek habitat than in open water habitats (open water = 5.5, tidal creek = 6.4; p = 0.084), but J' (open water = 0.68, tidal creek = 0.65; p = 0.516) and H' (open water = 1.58, tidal creek = 1.67; p = 0.502) were similar. Similar trends were observed for both species numbers and diversity in previous survey periods (Van Dolah *et al*., 2002a, 2004a). While the number of species appears to be greater in tidal creek habitats, it is actually likely to be much greater in open water habitats (Box 3.4.3). Trawls in tidal creeks initially catch more species because fish and crustaceans occur at much higher densities there. However, open water habitats ultimately support more species, likely due to their proximity to the higher salinity open ocean and greater diversity of habitat types. This highlights the different roles filled by these habitats. Productive tidal creek habitats provide forage and nursery habitat for high-density populations of fish and crustaceans, while open water habitats serve as reservoirs of biodiversity.

The 50 most numerically abundant taxa comprised 99.8% of the overall abundance across all stations and included 23 recreationally and/or commercially important species (Table 3.4.4). The five most numerically abundant species were white and brown shrimp (*Litopenaeus setiferus* and *Farfantepenaeus aztecus*), pinfish (*Lagodon*

Box 3.4.3 Large Finfish and Crustacean Biodiversity

How many species of large demersal finfish and crustaceans use South Carolina's estuarine environments?

Answering this question requires the application of species-area or species accumulation curves, a technique that examines how rapidly the total number of species captured accumulates as one makes more collections. The graphic below shows the total number of species captured by trawling as a function of the total distance trawled and the total number of individual organisms captured. Notice that because finfish and crustaceans occur at much higher densities in tidal creeks, the number of species caught increases rapidly with trawling effort. However, with further trawling effort, the number of new species caught slows much more than in open water habitats. In open water habitats, the number of new species accumulates more slowly than in tidal creeks at first, but even after having trawled for approximately 90 km, the number of new species is still increasing. By extending these lines out until they become horizontal (to the point at which new species are no longer being captured with additional sampling effort), the total number of species using each habitat can be predicted. Applying this technique, South Carolina's tidal creek habitats are predicted to support approximately 89 large finfish and crustacean species while open water habitat are predicted to support approximately 138.



Species accumulation curves for all six years of SCECAP monitoring.

rhomboides), spot (*Leiostomus xanthurus*), and Atlantic croaker (*Micropogonias undulatus*). These recreationally and/or commercially important species accounted for 80% of all fish and crustaceans captured. Three of the five most numerically dominant taxa collected in 2003-2004 (*L. setiferus, F. aztecus, L. xanthurus*) were also among the five dominant taxa collected in both previous survey periods (Van Dolah *et al*., 2002a, 2004a). In open water habitats, the five most numerically abundant taxa were white shrimp, Atlantic croaker, brown shrimp, spot, and weakfish (*Cynoscion regalis*), species that comprised approximately 72% of the total abundance of fish and crustaceans in this habitat. In tidal creek habitats, the five most numerically abundant taxa were white shrimp, pinfish, brown shrimp, spot, and brief squid (*Lolliguncula brevis*), species that comprised more than 87% of the total abundance in this habitat. White shrimp, the most abundant species in both open water and tidal creek habitats, were found in significantly greater numbers in tidal creek habitats ($p = 0.005$) than in open water habitats. With the exception of

Table 3.4.4. The mean densities (number per hectare) and percent occurrence of the 50 numerically most abundant taxa collected by trawl in tidal creek and open water habitats during 2003-2004. Recreationally-important species are shown in bold text.

		Open Water		Tidal Creek	
Species Name	**Common Name**	**Mean Abundance (#/hectare)**	**Percent of Stations Where Present**	**Mean Abundance (#/hectare)**	**Percent of Stations Where Present**
Litopenaeus setiferus	**White shrimp**	125.4	48	569.9	67
Farfantepenaeus aztecus	**Brown shrimp**	42.7	62	97.6	73
Lagodon rhomboides	**Pinfish**	21.0	23	104.5	58
Leiostomus xanthurus	**Spot**	36.2	67	83.1	75
Micropogonias undulatus	**Atlantic croaker**	47.8	50	9.4	43
Lolliguncula brevis	Brief squid	16.1	50	38.2	55
Bairdiella chrysoura	**Silver perch**	3.5	32	33.2	53
Cynoscion regalis	**Weakfish**	27.6	37	3.3	22
Stellifer lanceolatus	Star drum	23.0	28	7.6	13
Anchoa mitchilli	Bay anchovy	6.6	33	17.9	48
Trinectes maculatus	Hogchoker	5.9	42	13.3	42
Callinectes sapidus	**Blue crab**	3.0	27	14.5	43
Chaetodipterus faber	**Atlantic spadefish**	2.6	23	6.8	25
Selene vomer	Lookdown	6.0	23	3.3	22
Callinectes similis	Lesser blue crab	2.8	15	3.7	25
Ictalurus furcatus	**Blue catfish**	0.7	7	5.6	8
Orthopristis chrysoptera	Pigfish	1.3	15	5.0	25
Chloroscombrus chrysurus	Atlantic bumper	2.6	12	1.2	3
Gerreidae	Mojarras	1.0	8	2.3	10
Opsanus tau	Oyster toadfish	0.2	5	2.3	15
Paralichthys lethostigma	**Southern flounder**	0.5	12	1.7	18
Prionotus scitulus	Leopard searobin	2.0	8	0.1	2
Chilomycterus schoepfi	Striped burrfish	0.2	7	1.7	17
Centropristis striata	**Black sea bass**	0.2	3	1.7	3
Stephanolepis hispidus	Planehead filefish	0.6	7	0.9	7
Paralichthys dentatus	**Summer flounder**	0.8	10	0.6	7
Menticirrhus americanus	**Southern kingfish**	0.5	8	0.7	7
Brevoortia tyrannus	Atlantic menhaden	0.2	3	1.1	7
Selene setapinnis	Atlantic moonfish	1.2	2	0.0	0
Dasyatis sabina	Atlantic stingray	0.4	7	0.7	7
Symphurus plagiusa	Blackcheek tonguefish	0.4	10	0.6	8
Citharichthys spilopterus	Bay whiff	0.2	5	0.7	10
Gymnura micrura	Smooth butterfly ray	0.1	3	0.7	7
Menticirrhus sp.	**Kingfish**	0.5	8	0.2	3
Peprilus alepidotus	Harvestfish	0.7	5	0.0	0
Lepisosteus osseus	longnose gar	0.0	0	0.6	7
Prionotus tribulus	Bighead searobin	0.6	10	0.0	0
Anchoa hepsetus	Striped anchovy	0.4	8	0.1	2
Farfantepenaeus duorarum	**Brown-spotted shrimp**	0.1	2	0.5	3
Etropus crossotus	Fringed flounder	0.0	0	0.5	5
Mugil cephalus	**Striped mullet**	0.0	0	0.5	5
Synodus foetens	Inshore lizardfish	0.0	0	0.5	5
Centropristis philadelphica	Rock sea bass	0.0	0	0.5	5
Dasyatis sayi	Bluntnose stingray	0.4	5	0.0	0
Rhizoprionodon terraenovae	**Atlantic sharpnose shark**	0.3	7	0.1	2
Cynoscion nebulosus	**Spotted sea trout**	0.0	0	0.4	3
Archosargus probatocephalus	**Sheephead**	0.1	2	0.2	2
Scomberomorus maculatus	**Spanish mackerel**	0.1	3	0.1	2
Ictalurus catus	**White catfish**	0.0	0	0.2	2
Lepomis sp.		0.0	0	0.2	2
Pomatomus saltatrix	**Bluefish**	0.0	0	0.2	2

Atlantic croaker, the abundance of the other dominant organisms was also significantly greater in tidal creek habitats than in open water habitats.

There are currently no formal indices of estuarine habitat condition applicable to the southeastern US using large crustacean and fish communities. However, using percentiles, areas supporting unusually low crustacean and fish densities and biodiversities can be identified. The 10th, 25th and 50th percentiles of mean densities, mean species number, and mean community diversity (H') in open water and tidal creek habitats are presented in Table 3.4.5. Two open water stations and two tidal creek stations (RO036057, RO046070, RT042064, and RT042070) fell below the 10th percentile for each of these metrics. Based on the overall integrated measure of habitat quality (Appendix 2), only RT042070 was coded as not having good habitat quality. Located on a tributary of the Cooper River upriver from Grove Creek in the Charleston area, this station had only a fair overall habitat quality score, with a good water quality score, but fair condition for sediment quality and poor for benthic community condition.

Recreationally and Commercially Important Species:

Recreationally and commercially important fish and crustaceans collected during the 2003-2004 sampling season included 23 species and accounted for 88% of the total abundance of organisms in the trawls (Table 3.4.4; data online). During the 1999-2000 and 2001-2002 survey periods, these taxa comprised 75% and 84% of the total abundance, respectively. Recreationally and commercially important taxa were significantly more abundant in tidal creek habitats (average = 935 indiv/ha) than in open water habitats (314 indiv/ha) during the 2003-2004 survey period ($p = 0.013$). A significantly greater number of recreationally or commercially important species also were found in tidal creek habitats (4.0 species per trawl) than in open water habitats (3.2 species/trawl; $p = 0.005$) even though the trawls in tidal creeks were half the length of those in open water habitats (0.25 km vs. 0.50 km).

The mean densities of selected species over the six-year period from 1999 to 2004 do not suggest any consistent pattern of increase or decline across the various species assessed (Figure 3.4.8). In open water habitats, white shrimp, weakfish, and spot showed slightly increasing abundance over time. In tidal creek habitats, white shrimp also showed a slight increase in abundance while weakfish and brown shrimp showed slight decreases in abundance.

Since SCECAP started in 1999, the program has provided a source of fisheries-independent monitoring for species which are not otherwise monitored by SCDNR. These include several commercially and recreationally important fish species such as spot, weakfish, and Atlantic croaker. Changes in bag and size limits have been advocated recently for several species including weakfish. Our knowledge of the distributions and population dynamics of several of these species remains incomplete and the data collected by this monitoring program could help to fill some of the existing gaps. The SCECAP database also provides critical information on the distributions and population structures of many fish and invertebrates

Table 3.4.5. Mean values and the 10th, 25th, and 50th percentiles for density (individuals/hectare), number of species and overall community diversity (H') values for open water and tidal creek habitats.

	Density		Number of Species		Overall Community Diversity (H')	
	Open	Tidal	Open	Tidal	Open	Tidal
Mean	389	1042	5.6	6.5	1.58	1.67
10th percentile	36	186	2.5	3.0	0.72	0.78
25th percentile	73	288	3.0	4.9	1.13	1.20
50th percentile	197	485	5.3	6.8	1.55	1.73

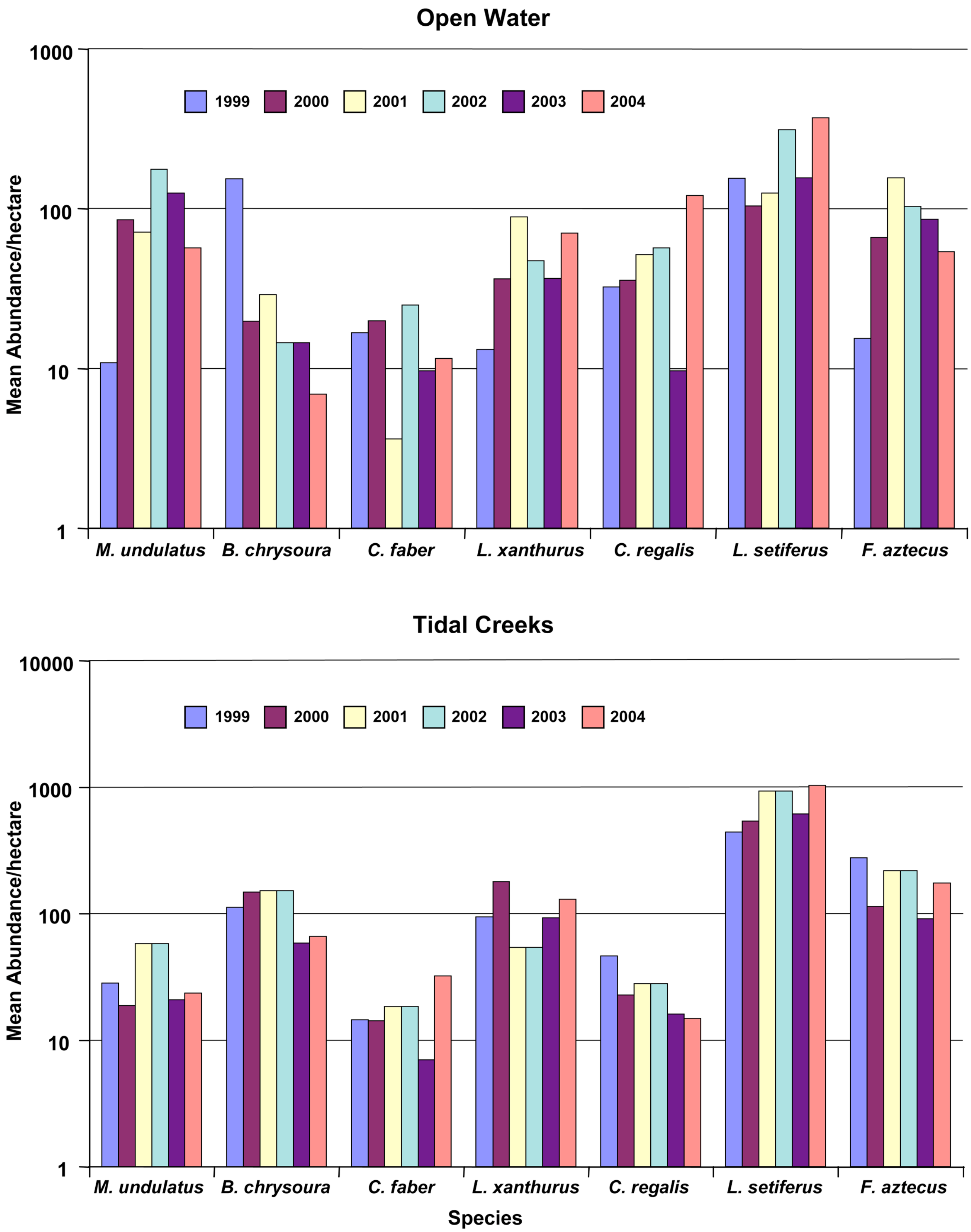


Figure 3.4.8 Mean abundances (number per hectare) of common commercially and recreationally-important fish and crustacean species in open water and tidal creek habitats between 1999 and 2004.

*Table 3.4.6 Priority Species for the South Carolina State Comprehensive Wildlife Conservation Plan that have been captured during the six years of SCECAP monitoring. * = species infrequently caught.*

Marine Fish	Marine Invertebrates
Atlantic Spadefish	Brief Squid
Bay Anchovy	Horseshoe Crab*
Atlantic Croaker	Lined Seahorse*
Kingfish	Stone Crab*
Southern Flounder	
Spot	
Tonguefish	
Crevalle Jack*	
Mummichog*	
Sheepshead*	
Striped Mullet*	

identified as "Priority Species" for the South Carolina State Comprehensive Wildlife Conservation Plan (Table 3.4.6). While other SCDNR programs provide data on some of these species, SCECAP remains the only source of information on many others.

Body Size:

The estuaries of South Carolina serve as nursery habitats for many estuarine and coastal species. Juvenile spot, Atlantic croaker, and penaeid shrimp often numerically dominate tidal creek habitats. An analysis of the length of spot, brown shrimp, and white shrimp from 2001-2004 generally supports this trend. Spot and white shrimp, two of the three most abundant species in both habitats, were significantly larger in open water habitats vs. tidal creek habitats ($p=0.002$ and $p<0.001$ respectively). The size of brown shrimp was not significantly different between the habitat types. However, brown shrimp spawn earlier in the year than do white shrimp, so by the time this program begins sampling (late June), the brown shrimp are fairly large and have begun to move from tidal creek habitats into open water habitats.

Tissue Contaminants:

Human activities can result in the release of contaminants (PAHs, heavy metals, PCBs and pesticides) into estuaries. These chemical compounds can accumulate in estuarine fauna through direct contact with contaminated water and sediments and can be transferred up the food chain from prey to predator. In order to evaluate the level of contamination of estuarine fauna in South Carolina, SCECAP monitors the levels of 93 different contaminants in the tissues of trawled fish. While these values do not necessarily indicate direct human health threats, they do provide a useful index of what contaminants are entering the estuarine food web and where estuarine fauna are most likely exposed to them. In general, the fish collected by SCECAP are small (mean = 10 cm in length), so whole fish are processed rather than just the fillets. The whole body contaminant data collected by SCECAP is an environmental measure of contaminants in fish tissues and should not be directly compared to edible tissue concentrations (fillets only) often used as a measure of risk to humans. Use of whole fish may underestimate the concentration of some contaminants (e.g., mercury) in edible tissue, but provides a better estimate of overall contaminant concentration in the organism.

For the 2003 and 2004 sampling periods, fish tissues were collected at 48 and 35 stations, respectively. The target species were spot (*Leiostomus xanthurus*) and croaker (*Micropogonias undulatus*), both benthic feeders with similar life histories in South Carolina estuaries. Between 2000 and 2003, other species such as pinfish were substituted when the target species were not collected in sufficient quantities. During 2004, tissue samples were taken only for spot and croaker, thus fewer stations had tissue contaminant data in 2004 relative to previous years.

Overall, the level of contamination of young spot and croaker in South Carolina estuaries is low (data online). Therefore, statistical analyses were performed on "total" values, the sums of all the analytes within each class (metals, PAHs, PCBs, and pesticides) for each station. Total metals in fish tissues showed a general trend of higher values in tidal creek habitats than in open water habitats, but total PAHs, total PCBs and total pesticides showed no significant difference between habitat types. Analyses of total contaminant values by year suggested only minimal changes from one year to the next and no generally increasing or decreasing trends across years. When comparing total contaminant values by station, only one station

(RT042079) had a maximum value for total metals that was greater than total metal values at stations found in previous survey periods (2000-2002).

Stations where individual contaminant concentrations in fish tissue exceeded the 90th percentile for tissue contaminants in the 2000-2002 SCECAP data set were also evaluated to identify potentially contaminated habitats. The number of contaminants that exceeded the 90th percentile were counted at each station, and stations were ranked based on the number of exceedences. Due to changes in the method detection limits for PAHs, these contaminants were left out of this analysis. Exceedence values ranged from zero (no contaminants exceeded their respective 90th percentile value) to 14 exceedences at station RT042194 in the upper Ashley River. Of the six random stations that had 7 or more exceedences, four of the stations were in suburban or urbanized rivers: RO036054 in Winyah Bay, RT042194 and RT032046 in the Ashley River, and RO046087 in the Beaufort River. The distribution of contaminated fish tissue in 2003-2004 was similar to previous survey periods where the most highly contaminated fish were caught in suburban and urban rivers such as the Ashley River and the upper part of Winyah Bay.

3.5 Incidence of Litter

Solid waste products, or litter, represent an inevitable consequence of human presence in natural systems. As development and recreational and commercial activities continue to increase in South Carolina's coastal zone, the amount of litter entering our estuaries, flushing into the open ocean, and washing up on beaches is expected to increase.

During 2003 and 2004, litter was visible in 13% of the state's tidal creek habitat and 3% of state's open water habitat. This represented a decrease since the 2001-2002 survey period (during which 20% of tidal creek and 8% of open water habitat had litter), but litter remained elevated well above the 1999-2000 levels (2% of tidal creek and 3% of open water habitat). Generally, the greater percentages of tidal creek sites having litter relative to open water sites likely reflects the closer proximity of tidal creeks to human populations as well as the presence of shoreline, vegetation and oyster reefs that can retain litter within the viewing distance of the survey crews. The reduction in litter over the previous survey period may reflect the flushing of litter out of our estuaries by increased freshwater inflow or just normal variability among survey periods. Considering the year-to-year variability, additional monitoring will be necessary to determine long term trends in litter.

3.6. Integrated Measures of South Carolina's Estuarine Habitat Quality

SCECAP is unique compared to most state and federal monitoring programs because it combines integrated measures of water quality, sediment quality, and biological condition into an overall measure of habitat quality at each site and for the entire coastal zone within its coverage area. Multi-metric measures provide a more reliable assessment than any single measure or group of measures representing only one component of the habitat. For example, poor or fair water quality based on state standards or historical data may not result in any clear evidence of impaired biotic communities. Many of South Carolina's state water quality standards are intentionally conservative to be protective and some contraventions of these standards are not severe enough to result in biological impairment. Similarly, fair or poor sediment quality may not result in degraded biotic condition because the organisms are either not directly exposed to the sediments (e.g., phytoplankton, fish) or because the contaminants are not readily bioavailable to the organisms. When two or more of the three measures (e.g., water quality, sediment quality, or biotic condition) are only fair or poor, there is increased certainty that the habitat may be limiting. While several studies have use a "triad" approach to measuring bottom sediment quality (e.g., Chapman, 1990; Chapman *et al.*, 1991), very few programs have been established elsewhere that use a more holistic approach that includes water quality variables. The USEPA National Coastal Assessment Program is the most successful federal program to use an approach similar to SCECAP, although the habitat metrics and method of integrating those metrics are very different (USEPA, 2001, 2004).

The overall index of habitat quality currently used by SCECAP is described by Van Dolah *et al.* (2004a, available online). This index weights each